RF Measurement Results of Buncher Cavity for Linac Pre-injector Upgrade

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I. Introduction

The buncher cavity (Figure 1) for Fermilab linac pre-injector upgrade is a capacitive loaded transmission line resonator. There are two gaps and drift tubes in this cavity. There is a metal grid at each end of the drift tube sections (Figure 2). The function of these grids is to enhance the E field in the gaps. The buncher cavity was fabricated by TIME Company and the grids were inserted at Fermilab. Bead-pull rf measurements were performed before and after the insertion of the grads. The purpose of the bead-pull measurement is to check the electric field profile along the center axis and the effect of the grids. The bead-pull and other rf measurement results in September, 2011 are reported in this technical report.

II. Bead-pull

The bead-pull measurements were performed in 3 configurations: (1) before insertion of the grads and string/bead was at the center of the drift tube; (2) before insertion of the grads and string/bead was displaced from center of the drift tube by 1 cm; and (3) after insertion of the grads and string/bead was at the center of the drift tube. In each configuration, the bead (made of brass) was moved vertically twice: upward and downward. So the data in Figure 5, 7, 9 and 11 are the reflection of those in Figure 4, 6, 8 and 10 through middle point between two peaks respectively. Shown in Figure 3 is the bead-pull setup. The bead pull system was modified from an existing one with a new step motor, control/data acquisition software and pulleys/supporting system.

The bead-pull measurement results are shown in Figure 4 – 11. Data in Figure 4 and 8 are re-plotted in Figure 10 and data in Figure 5 and 9 are re-plotted in Figure 11 for comparison. These data show that the E field in the gaps was increased by ~ 44% after the grids were inserted.

For a fixed setup and a small metal bead, the local electric field is related to the frequency shift caused by the perturbation of the metal bead as:

$$E^2 \propto (w/v)\Delta f/f0$$

where E is the amplitude of the local electric field, Δf is the frequency shift, $f0$ is the resonant frequency without perturbation, w is the stored energy and v is the volume of the bead.

III. Coupling

Shown in Figure 12 is the S11 measured at the input coupler port. It shows the input power coupler is adjusted to critical coupling with VSWR of 1.0015. The tuner position was at 5.440 (mm) and room temperature was 67º F.

IV. Pick-up loop attenuation

There are two pick up loops: #1 and #2. Their physical locations are shown in Figure 3. Shown in Figure 13 and 14 are S21 from input coupler port to pick up loop #1(-23.0 db) and loop #2 (-24.8 db) and the measured unloaded Q is 6820.

V. Tuning range

The resonant frequency can be adjusted by moving a metal tuner. Shown in Figure 15 is the resonant frequency versus the relative position of the tuner. Room temperature during the measurements was 67.5º F - 67.2º F. The total tuning range is from 201.134 MHz (Tuner at 0.1 mm) to 201.971 MHz (Tuner at 25 mm).

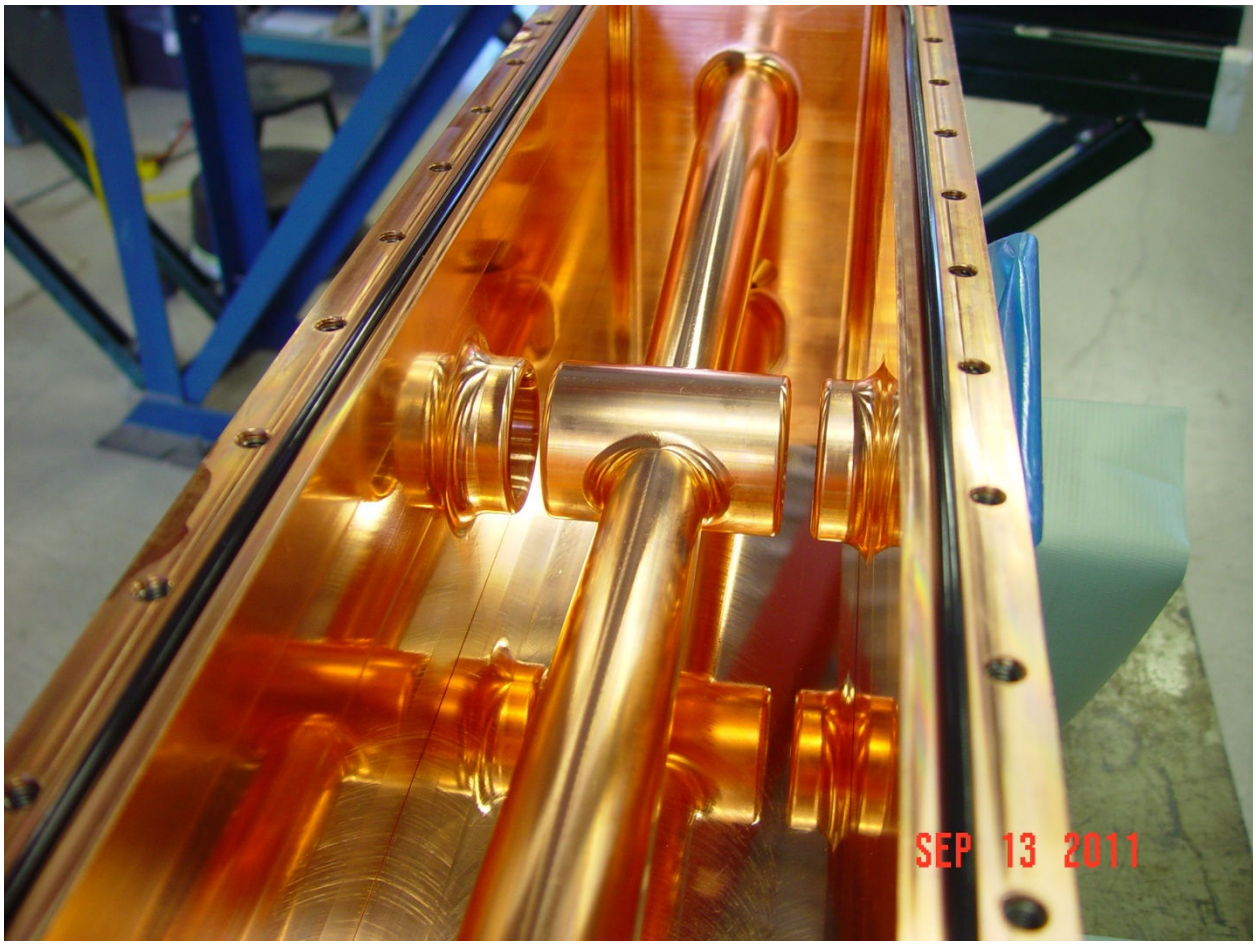

Figure 1. Buncher Cavity before grids were inserted.

Figure 2. Grids were inserted.

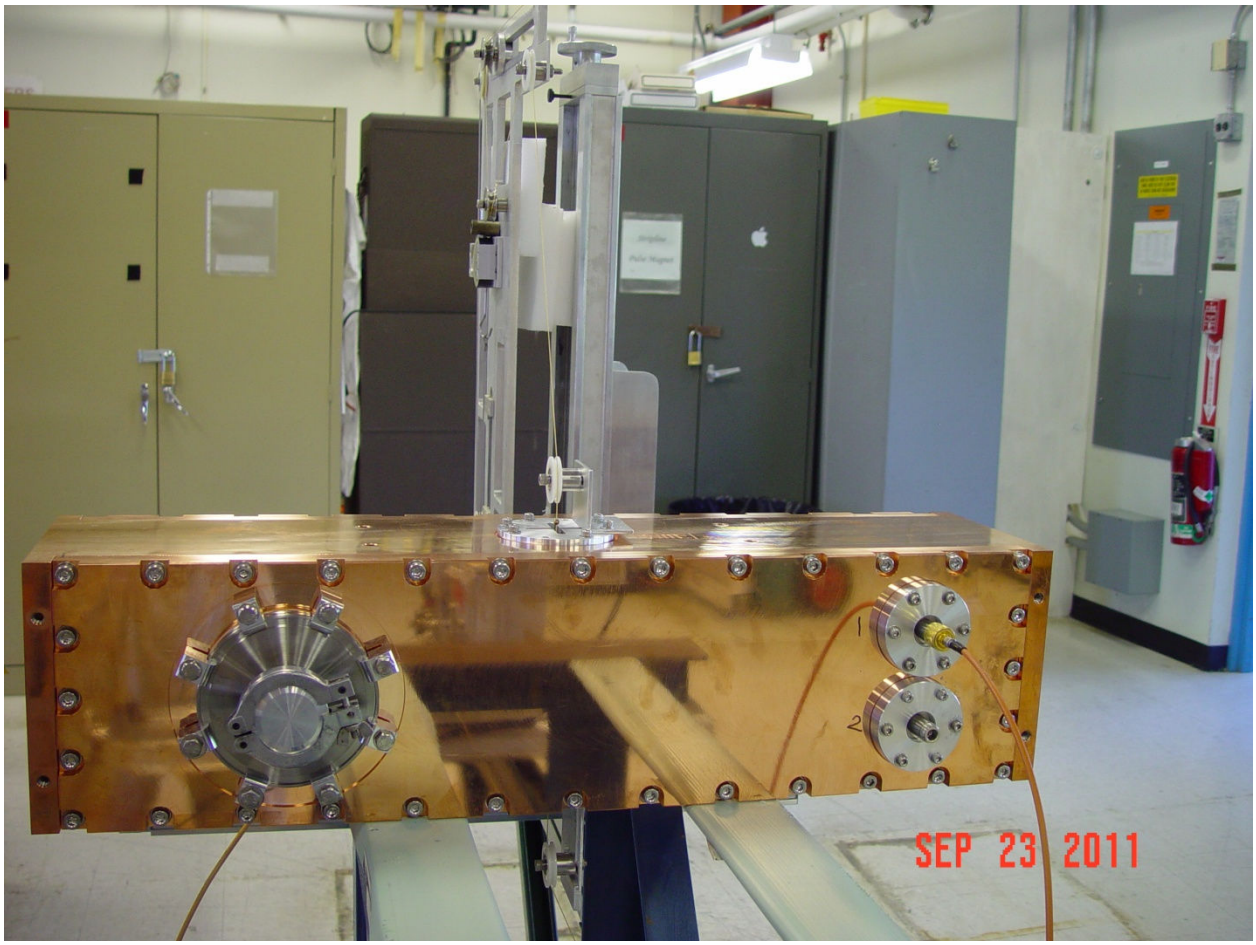

Figure 3. Bead-pull setup.

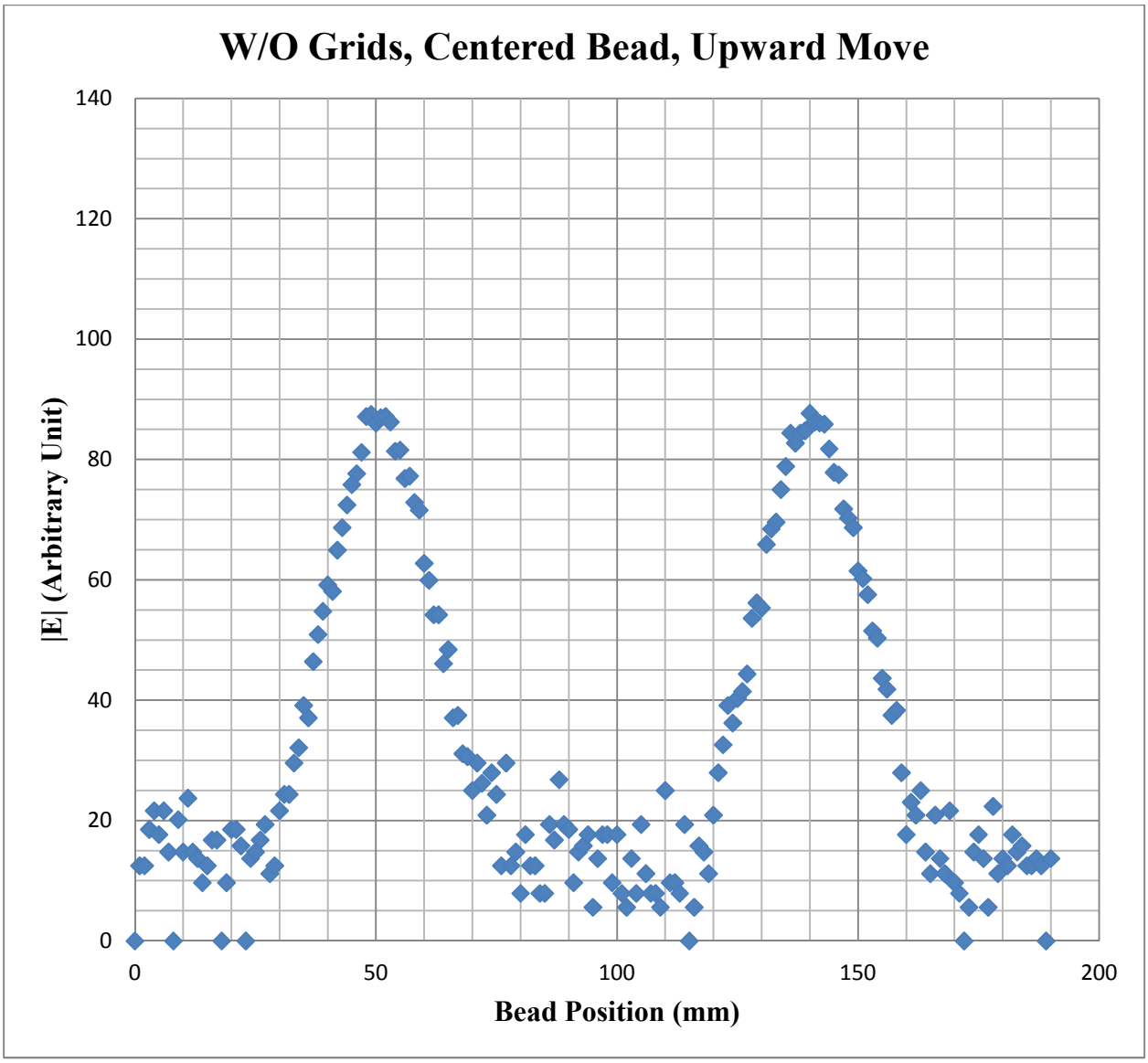

Figure 4. Bead-pull results, without grids, centered bead, upward move.

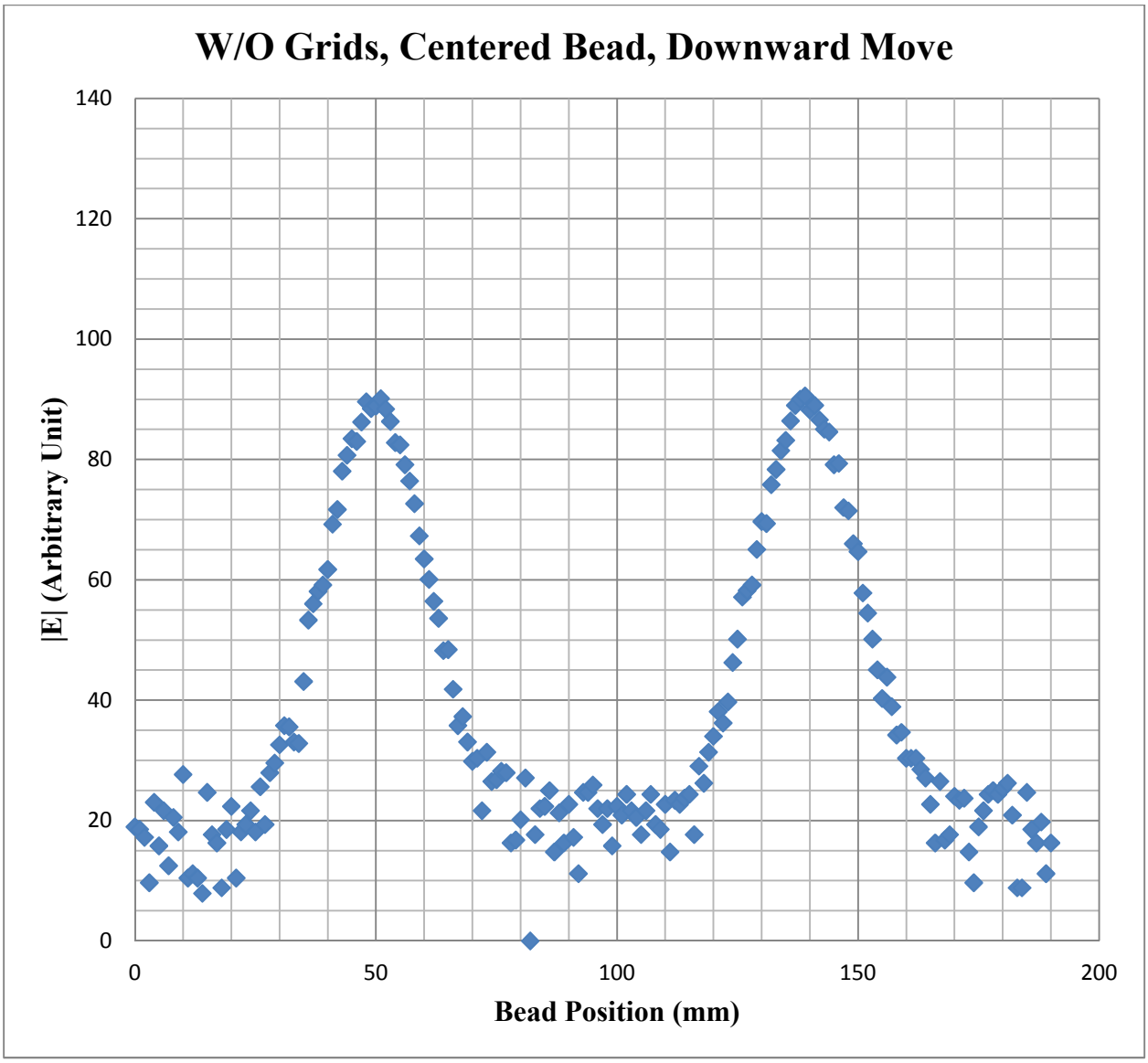

Figure 5. Bead-pull results, without grids, centered bead, downward move.

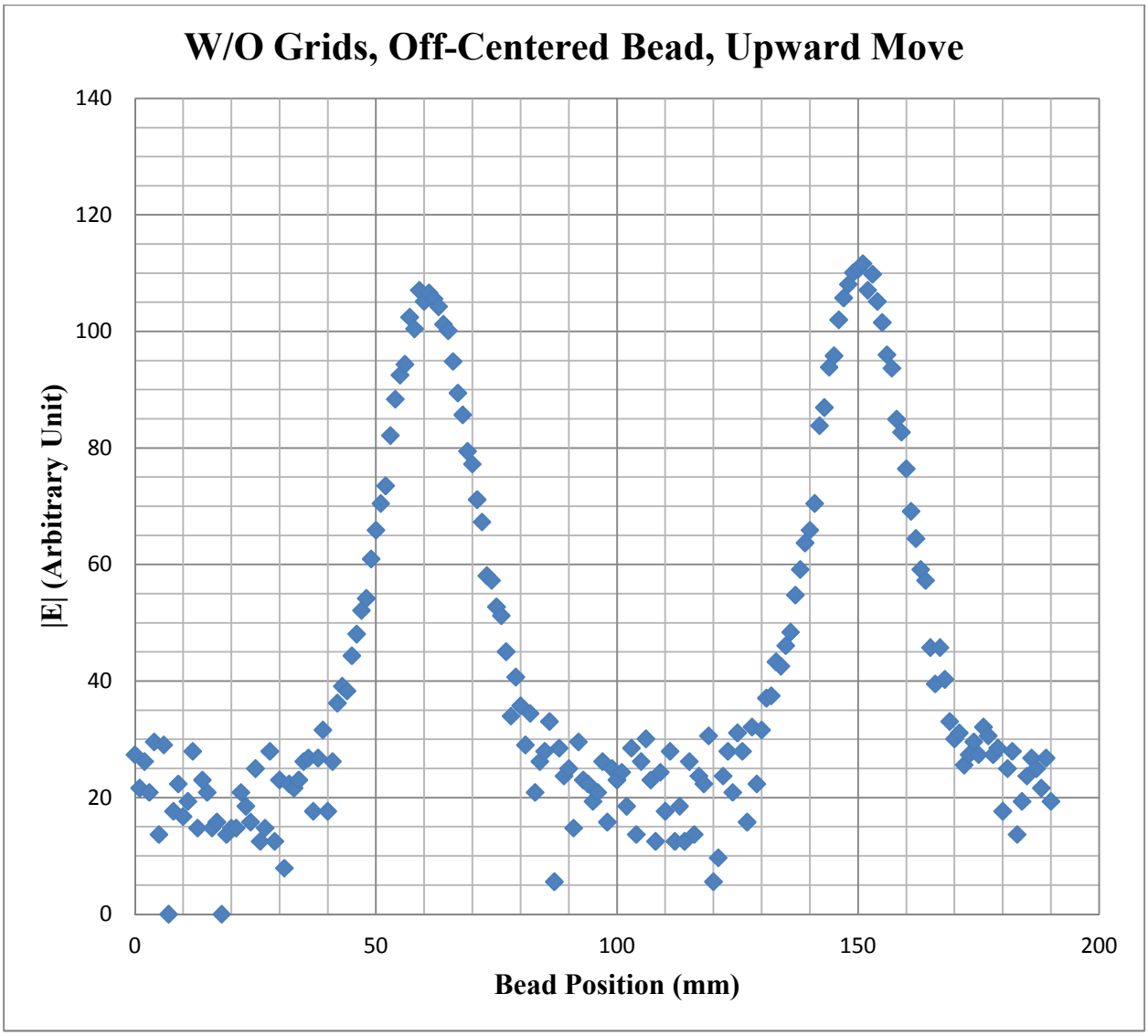

Figure 6. Bead-pull results, without grids, off-centered (1 cm) bead, upward move.

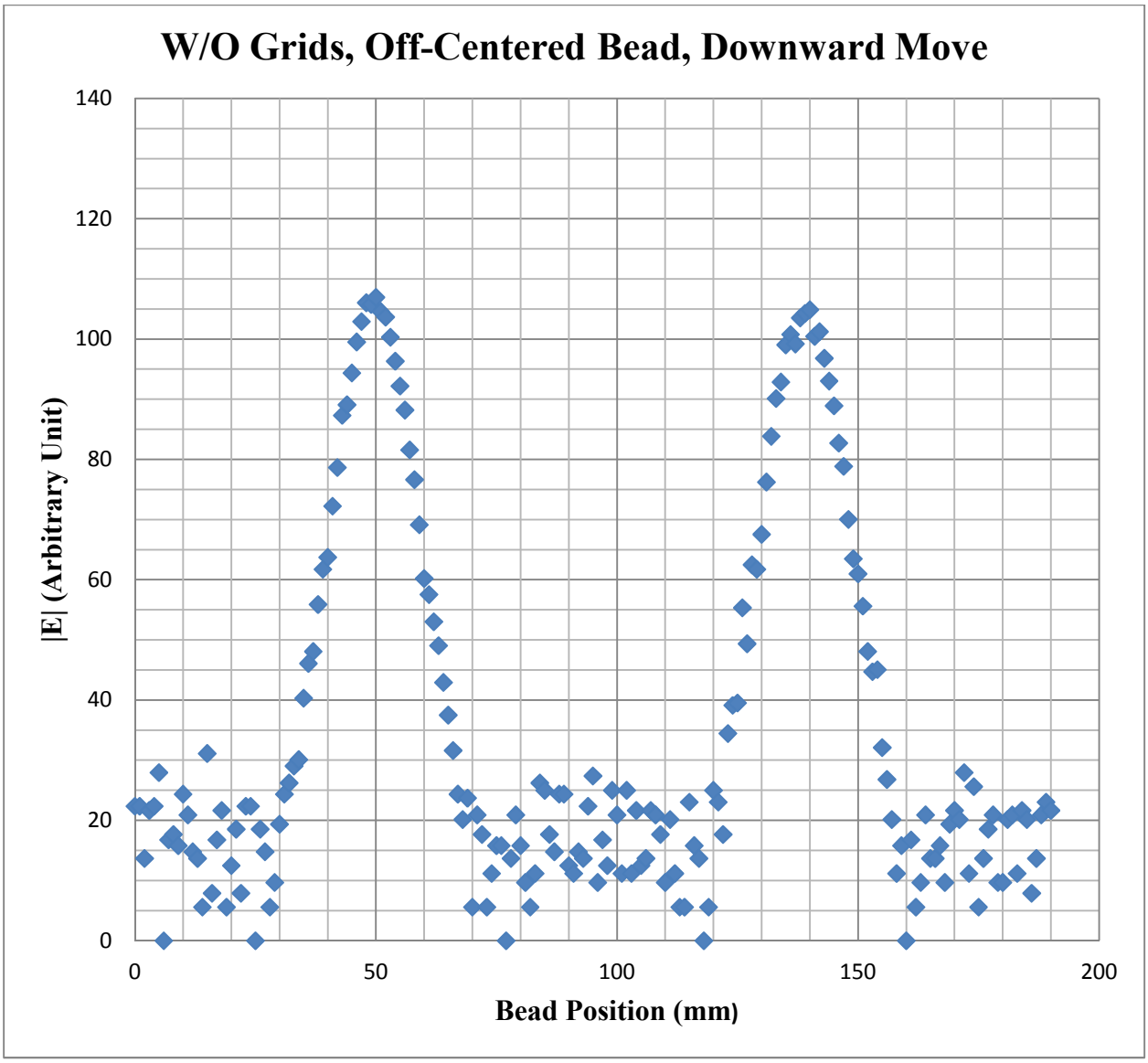

Figure 7. Bead-pull results, without grids, off-centered (1 cm) bead, downward move.

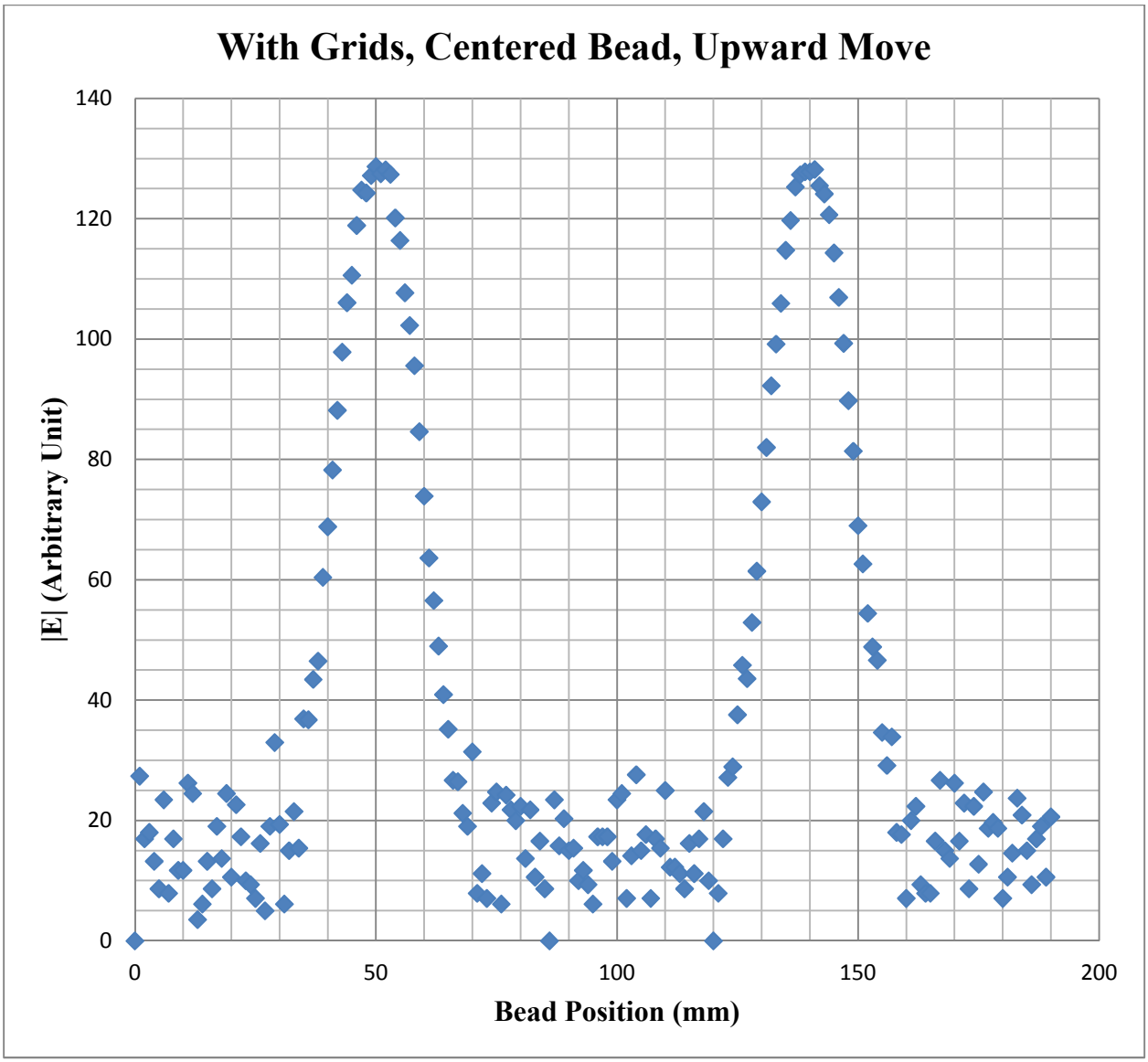

Figure 8. Bead-pull results, with grids, centered bead, upward move.

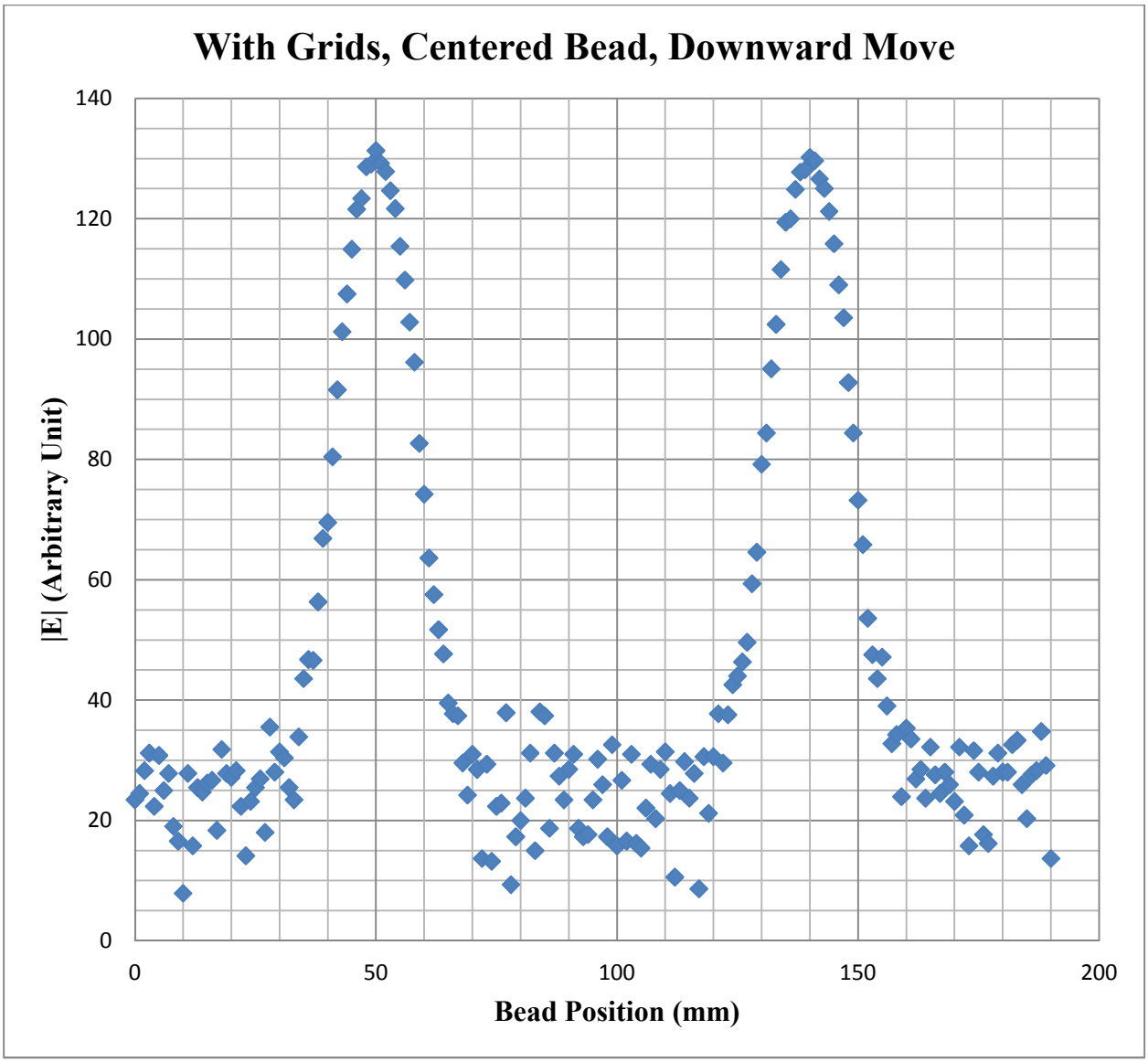

Figure 9. Bead-pull results, with grids, centered bead, downward move.

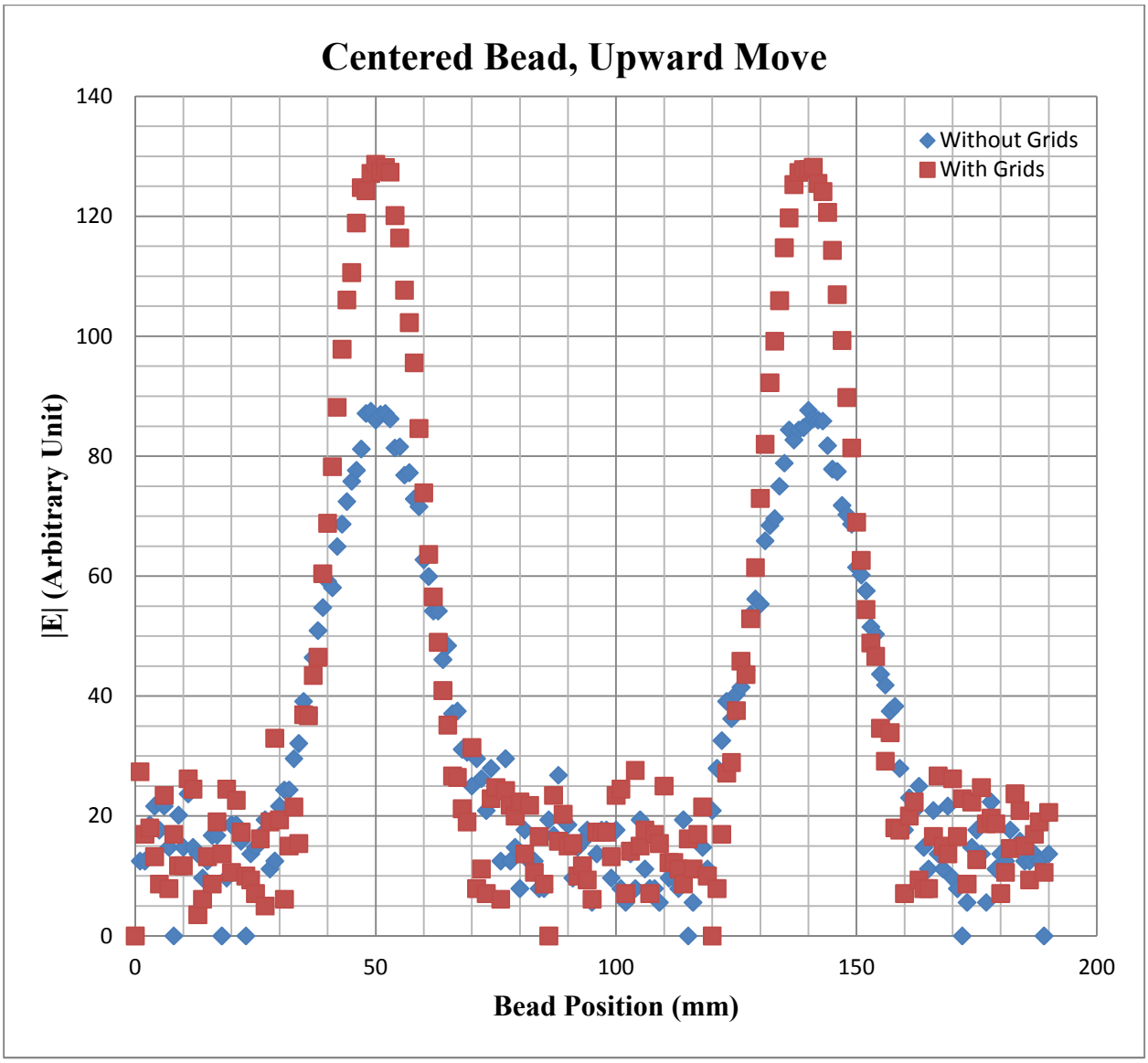

Figure 10. Compare data in Figure 4 (without grids) and Figure 8 (with grids), centered bead, upward move.

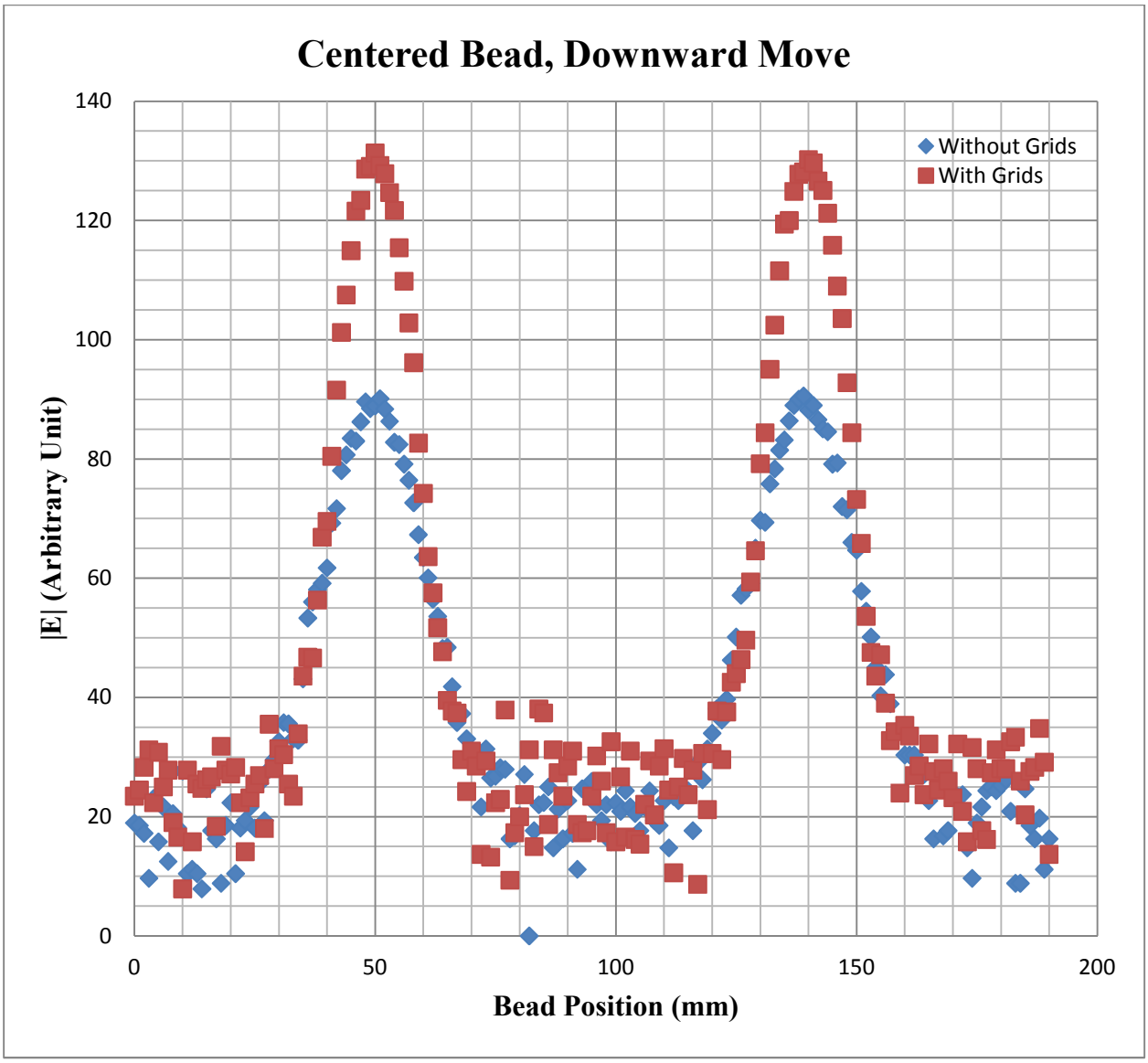

Figure 11. Compare data in Figure 5 (without grids) and Figure 9 (with grids), centered bead, downward move.

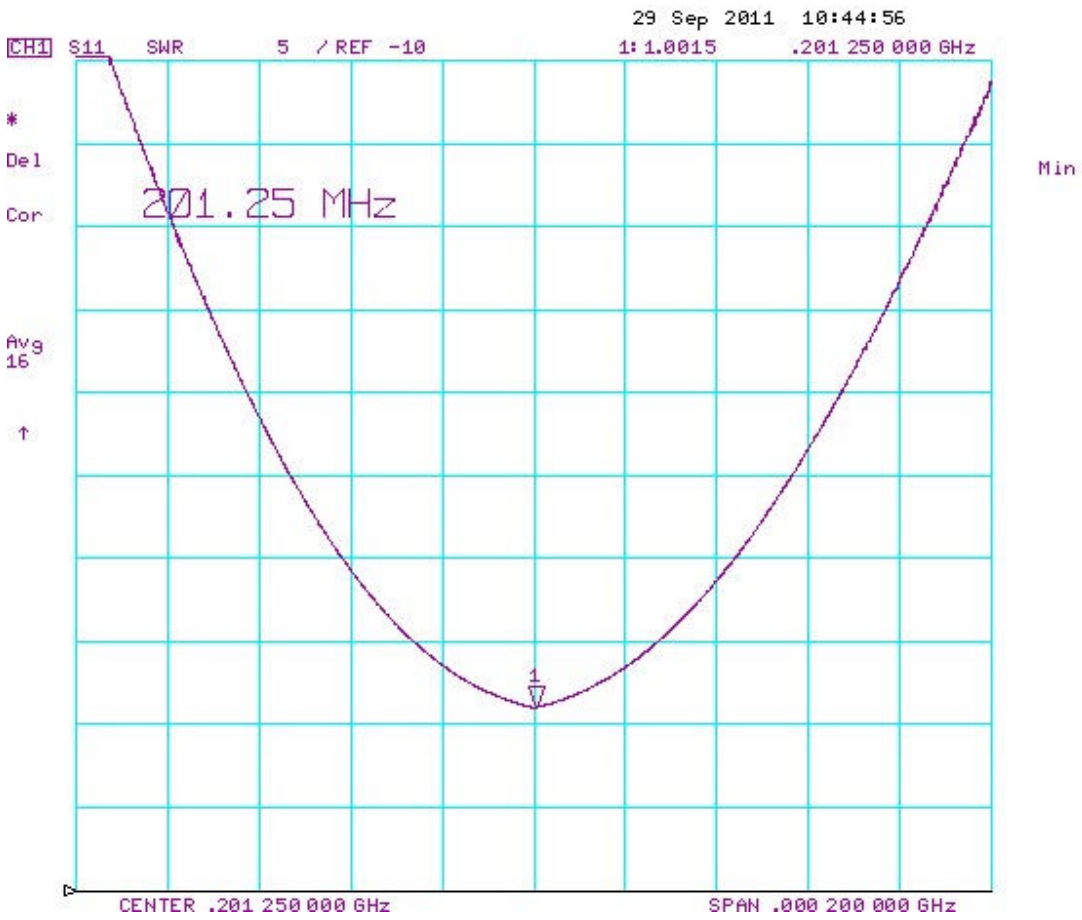

Figure 12. S11 at input coupler port.

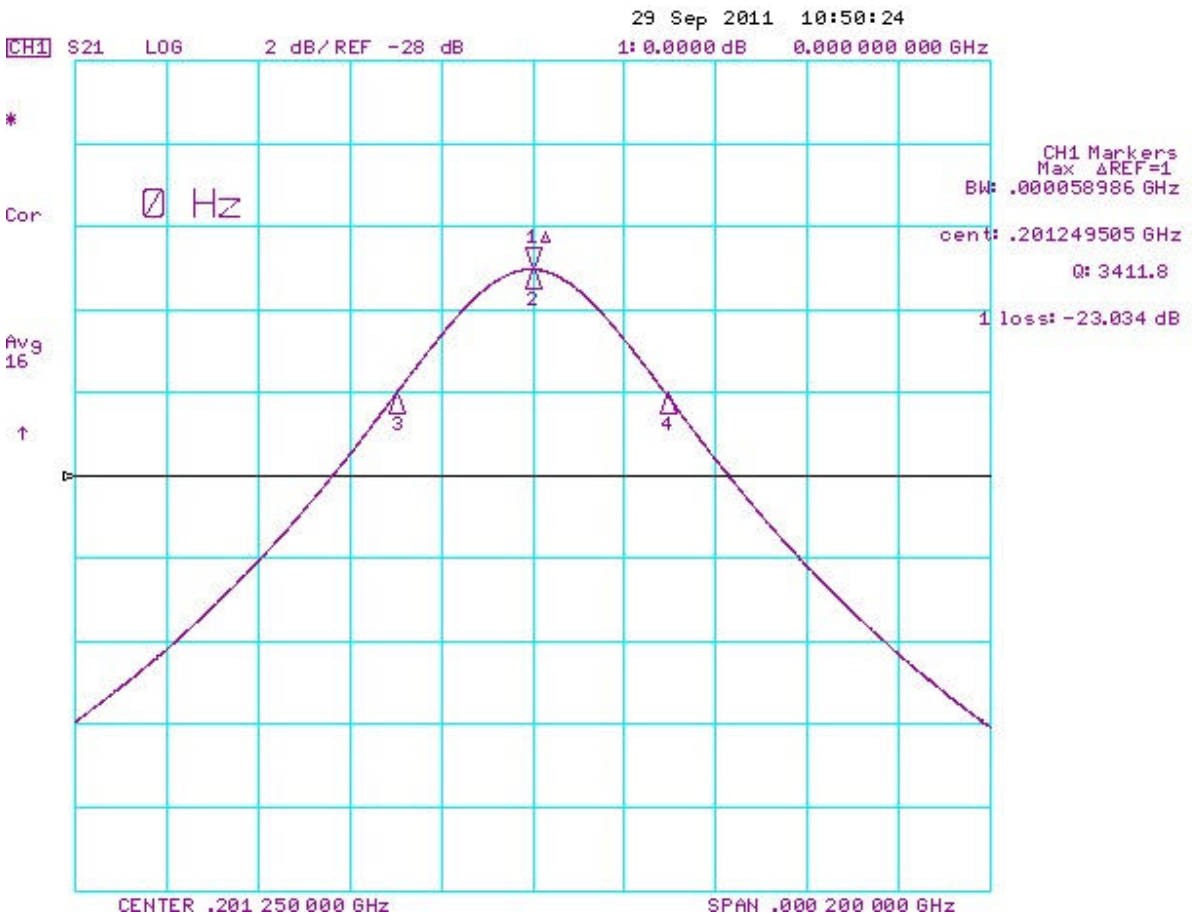

Figure 13. S21 from input coupler port to pickup port 1.

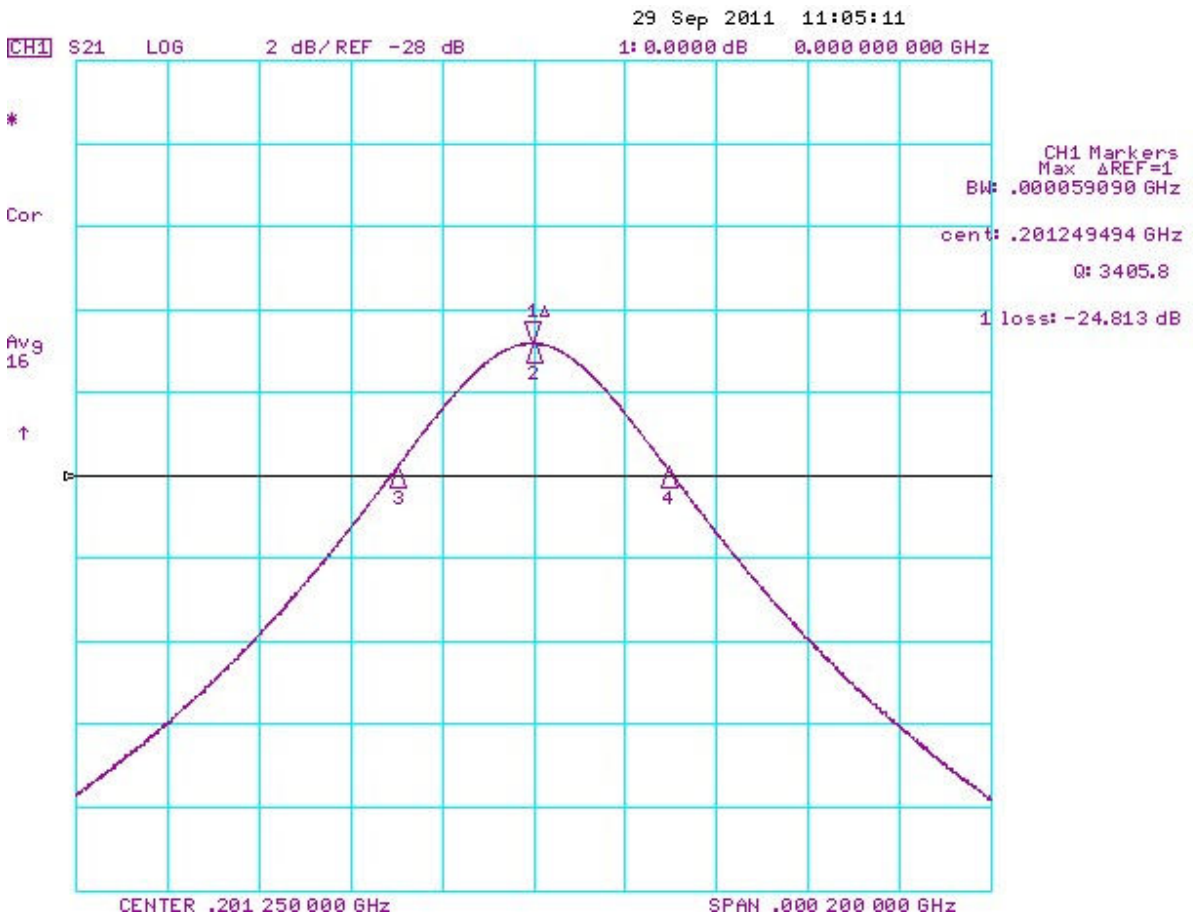

Figure 14. S21 from input coupler port to pickup port 2.

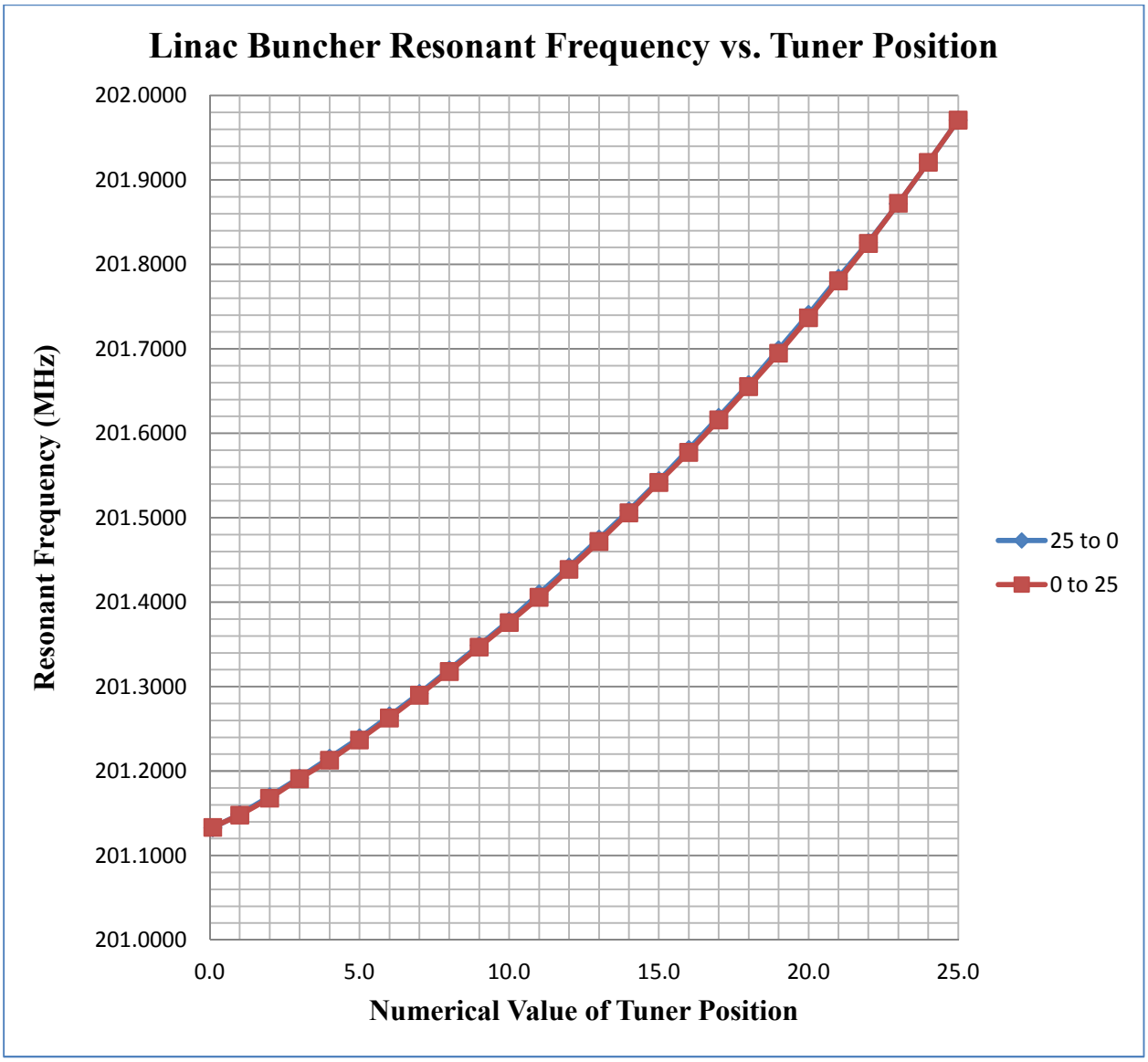

Figure 15. Resonant frequency vs. tuner position. (There are two sets of data in the plot: when tuner moves from 25 to 0 and from 0 to 25. The discrepancy between these two sets of data is ~ 5 KHz. The room temperature during these measurements was 67.5º F to 67.2º F).